Jet Propulsion Laboratory
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Uncertainties in the Antarctic Ice Sheet Contribution to Sea Level Rise: Exploration of Model Response to Errors in Climate Forcing, Boundary Conditions, and Internal Parameters

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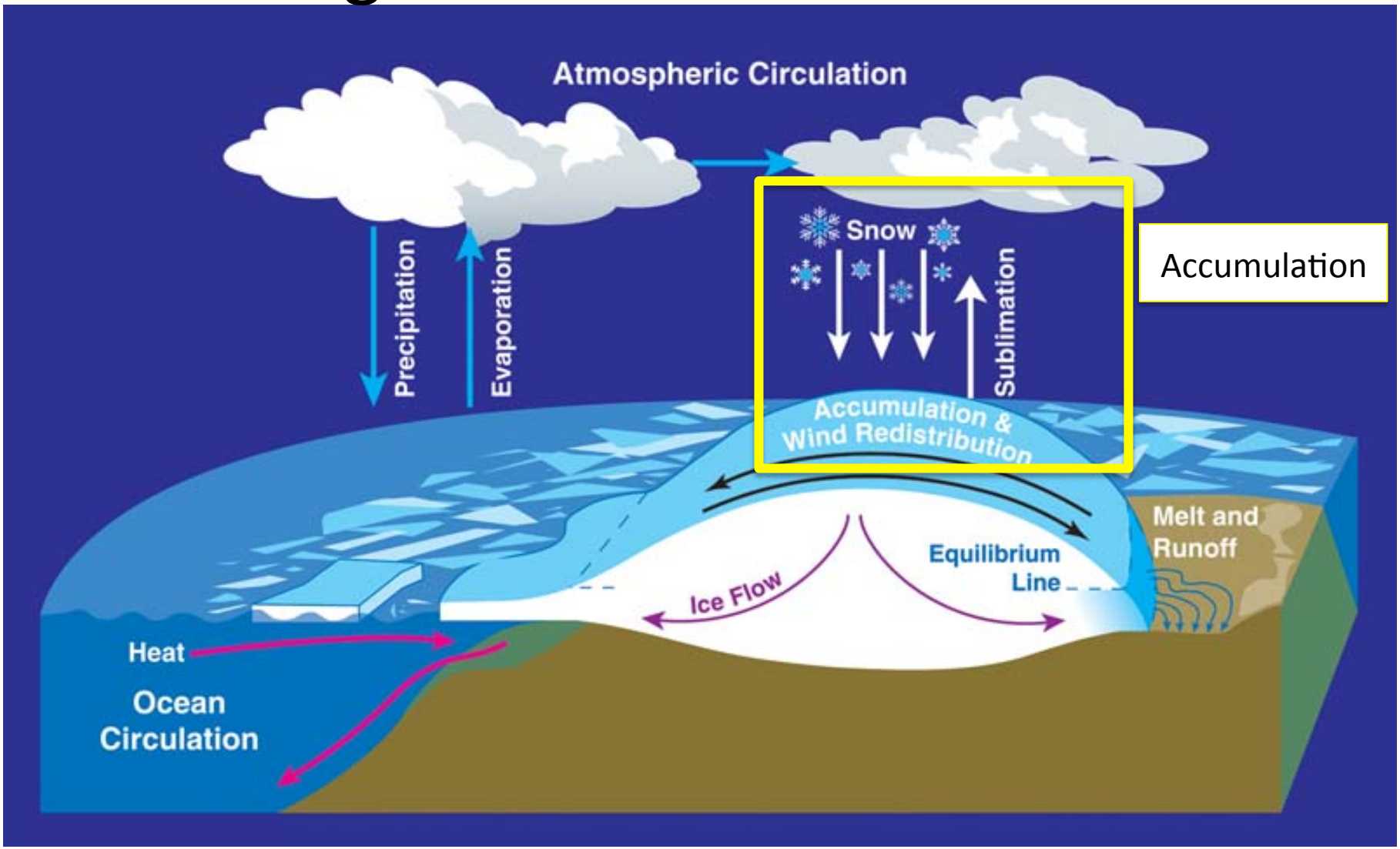
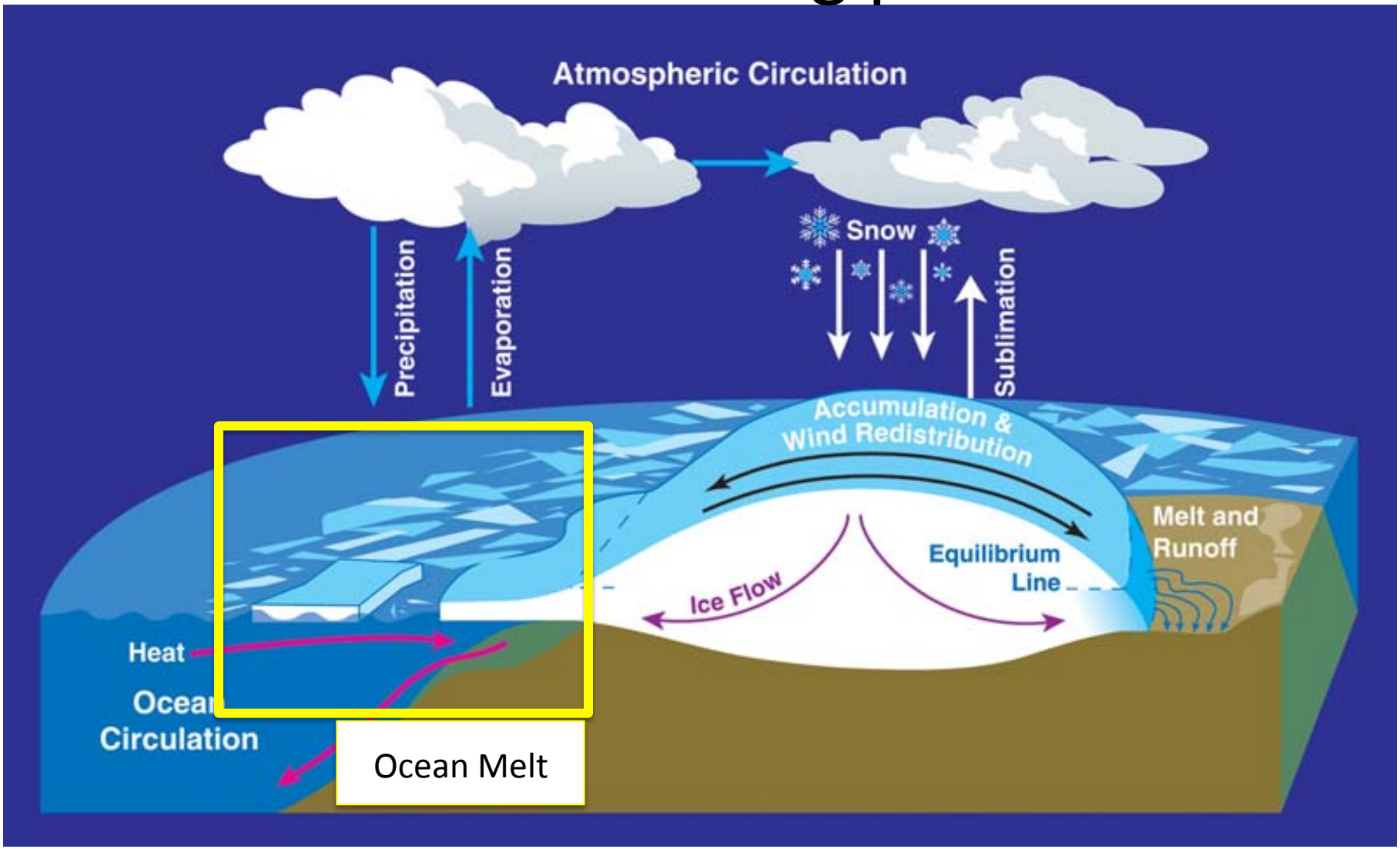
Model Forcing
and
Boundary Conditions

1. Accumulation is the key positive forcing of ice sheet mass balance



(Credit: NASA)

2. Ocean Melt removes ice from underneath the floating portions of ice



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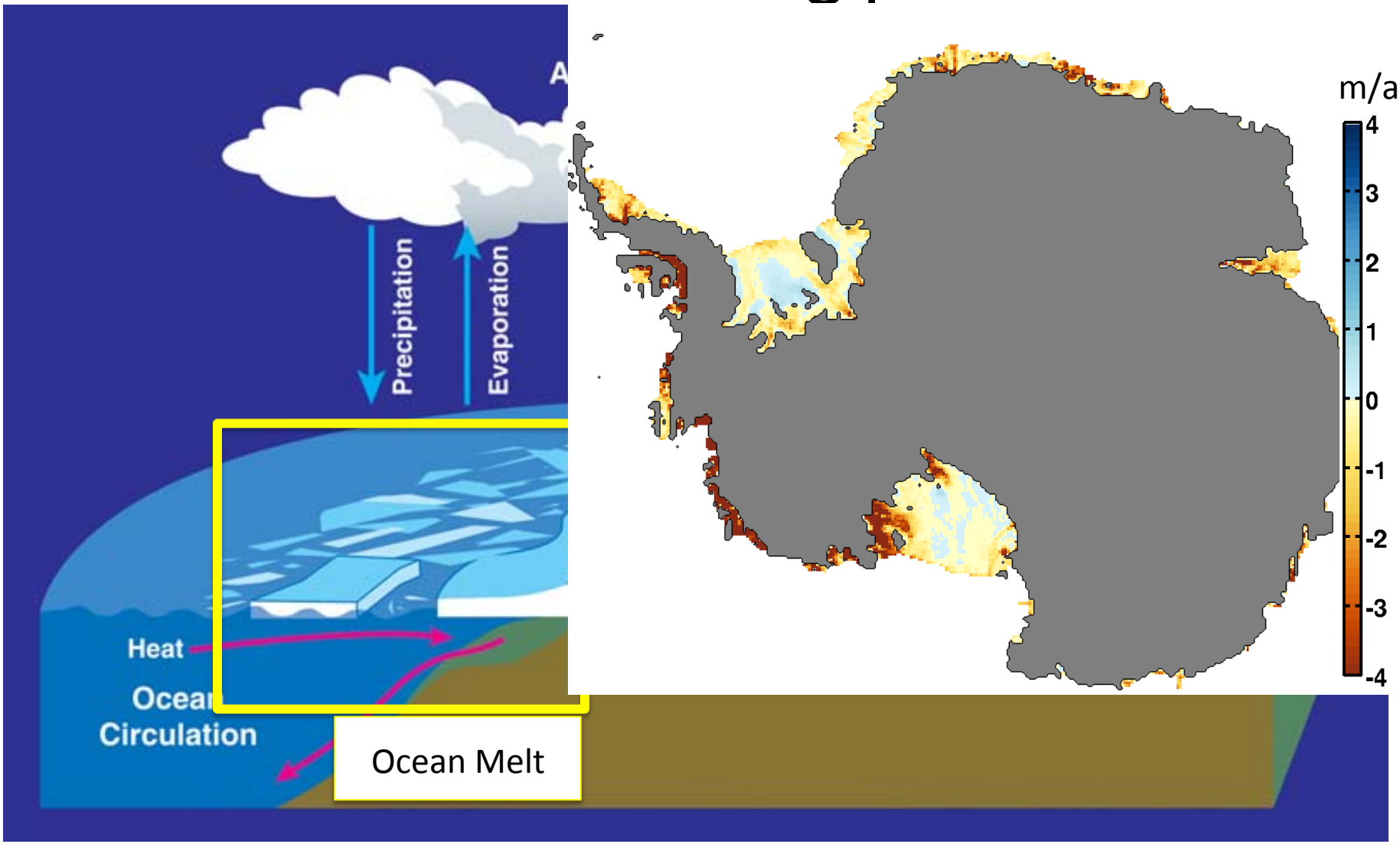
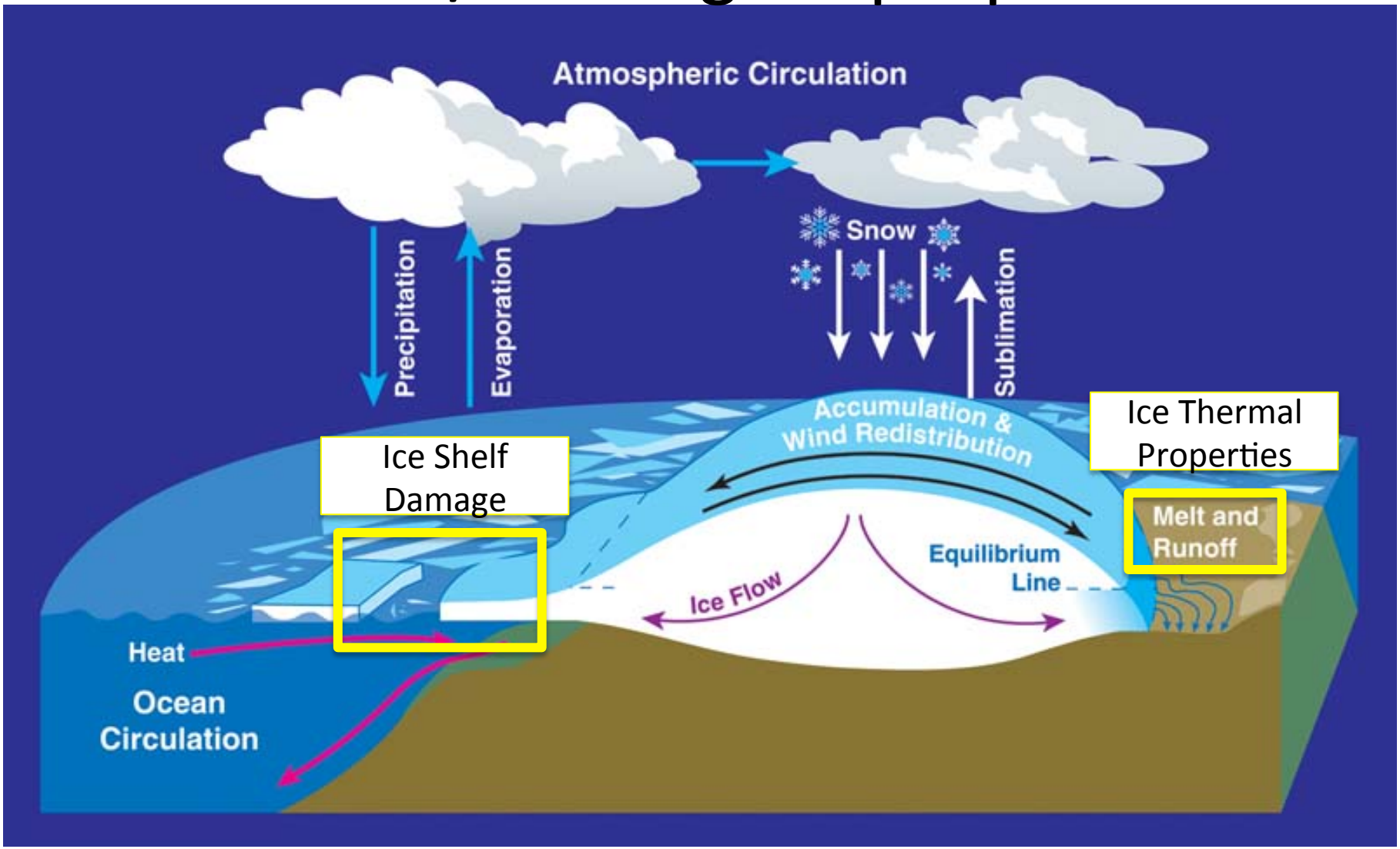


(Credit: NASA)

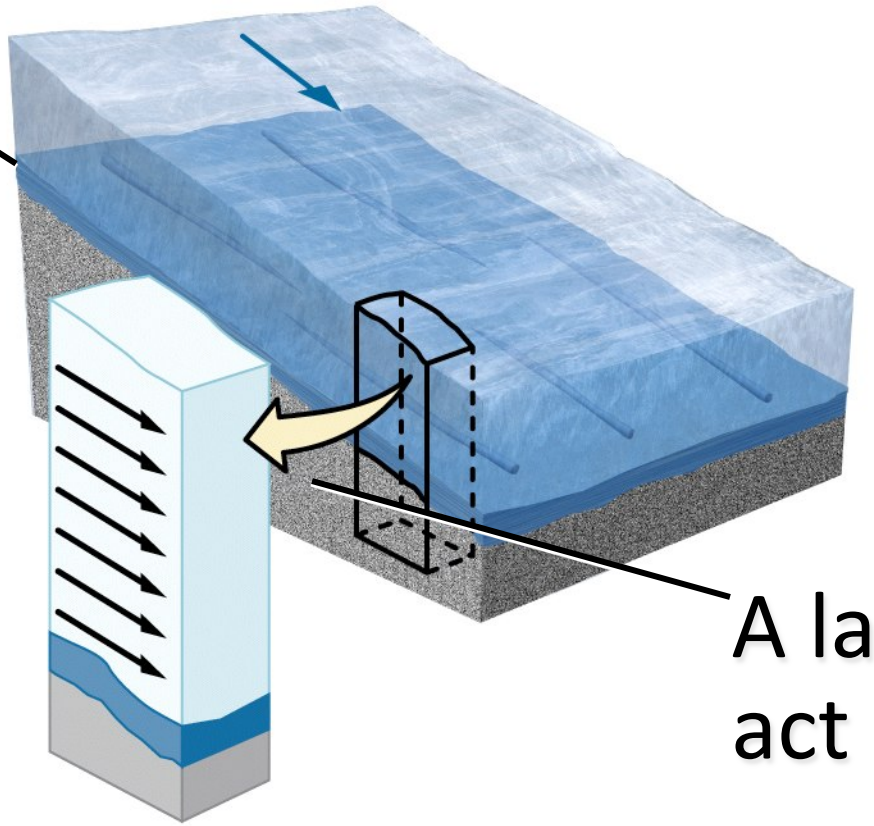
3. Ice Viscosity is dictated by ice thermal/rheological properties



(Credit: NASA)

4. Basal Friction is a large unknown for an ice sheet model, yet it dictates basal velocities

Less drag along the ice base (e.g. liquid water, weak bed)



A layer of water may act as a lubricant.

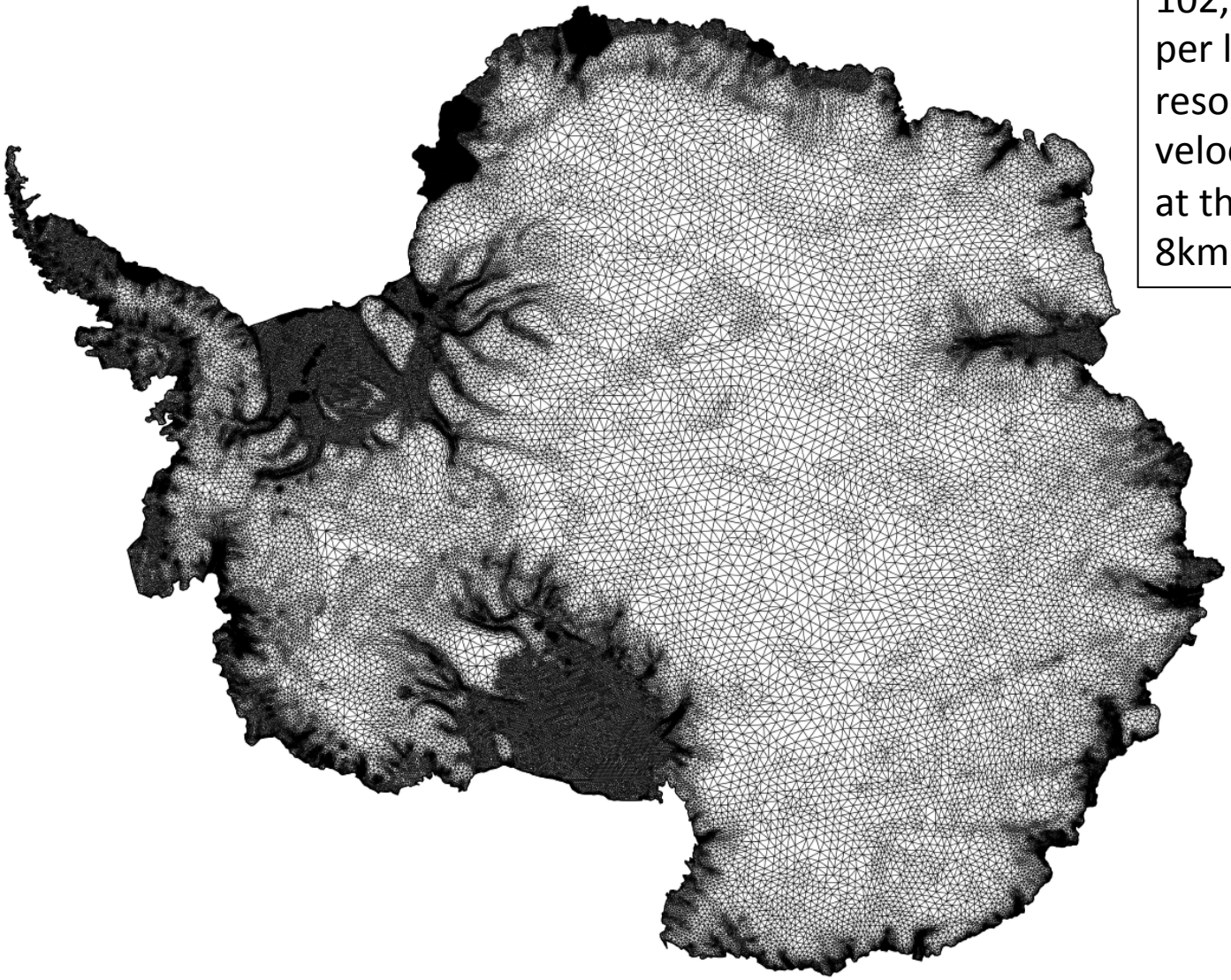
[i.e. Keisling et al., Ann. Glac, 2014]

Uncertainty Quantification Techniques:

ISSM-DAKOTA FRAMEWORK

- 100-year forward run forced with atmospheric boundary conditions from RACMO2 (mean annual 1979-2010).
- Ice shelve melt rates: from mean annual ECCO2-MITgcm 150-layer 9 km (2004-2013)

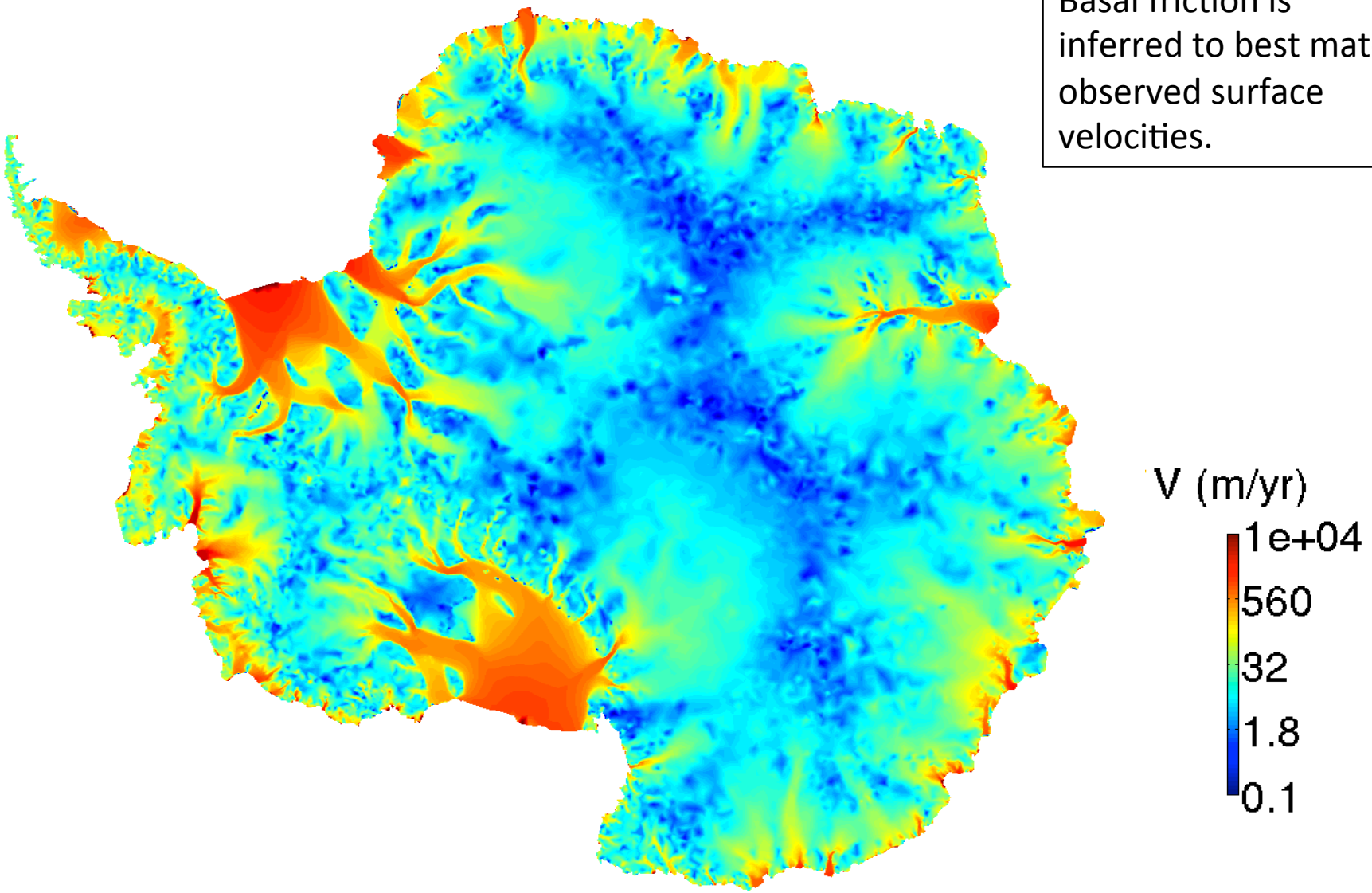
JPL-UCI Ice Sheet System Model (ISSM)
Antarctica Finite Element Mesh



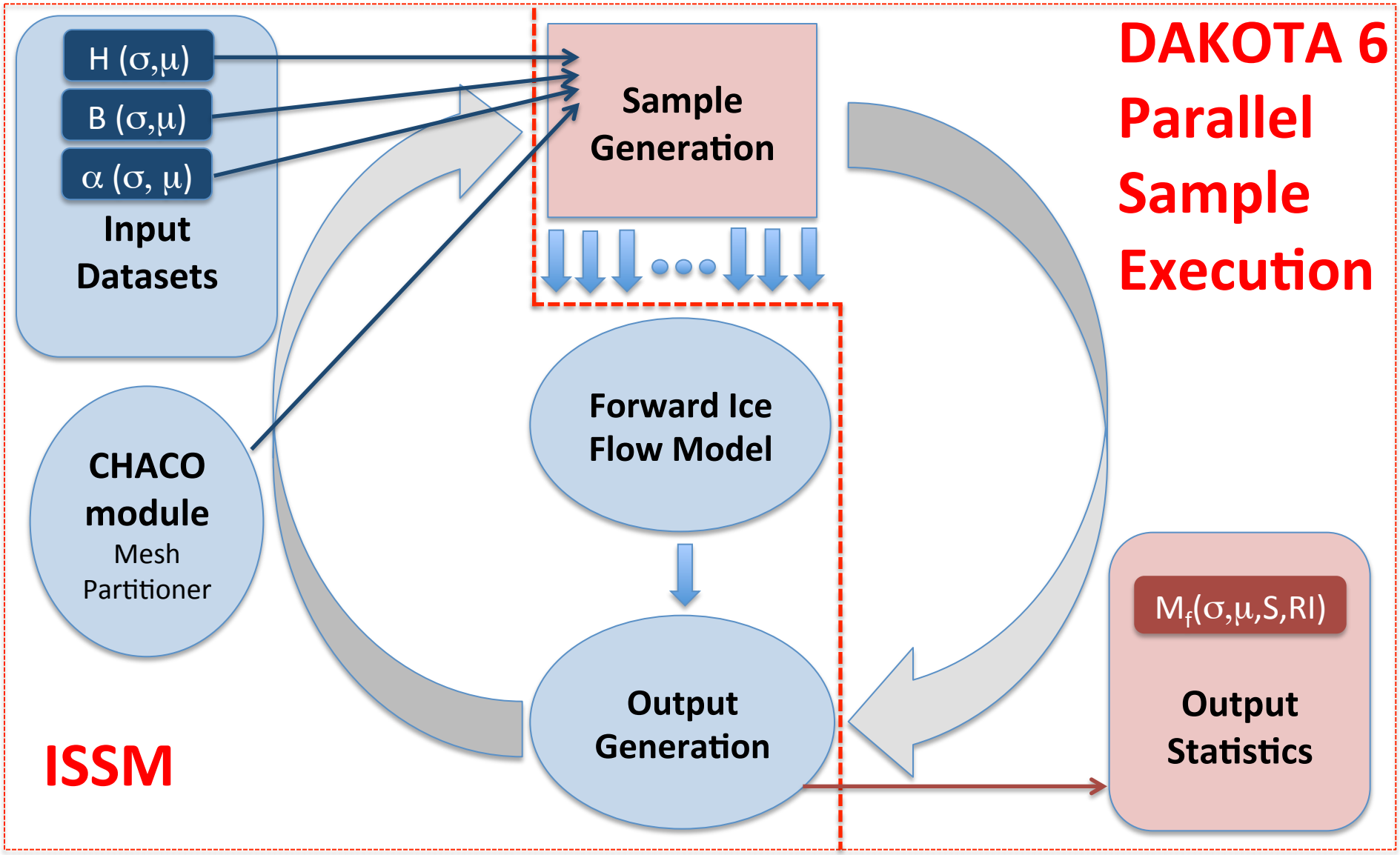
102,308 finite elements per layer, 3 km resolution in high velocity areas to 50 km at the divide, at least 8km on all ice shelves

ISSM modeled surface velocities result from inference of basal friction

Basal friction is inferred to best match observed surface velocities.



Design Analysis Kit for Optimization and Terascale Applications (DAKOTA) software is embedded into ISSM



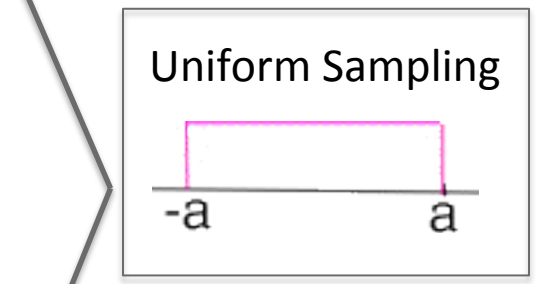
Continental-Scale Utility of

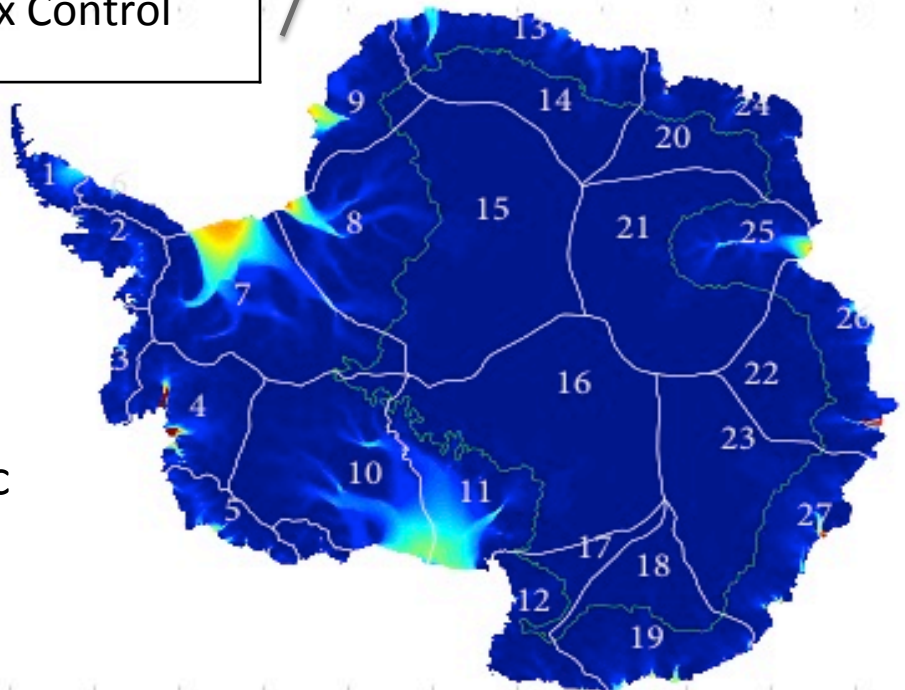
SAMPLING ANALYSIS

Uncertainty of projected extreme changes in Ice Sheet Mass?

We sample four variables in Antarctica with extreme values, using uniform sampling over 27 geographically-based partitions for 100 year period

Parameter/Forcing	Min	Max
Ice Shelf Melt	Minimum annual melt rates (ECCO2-MITgcm)	10 x Mean annual melt rates
Basal Drag	40% of Control	Control value
Ice Viscosity	60% of Control	Control value
Accumulation	50% of Control	2 x Control





27 Geographic Partitions

Sampling of individual variables independently highlights that ice shelf melt is a dominant contributor to sea level

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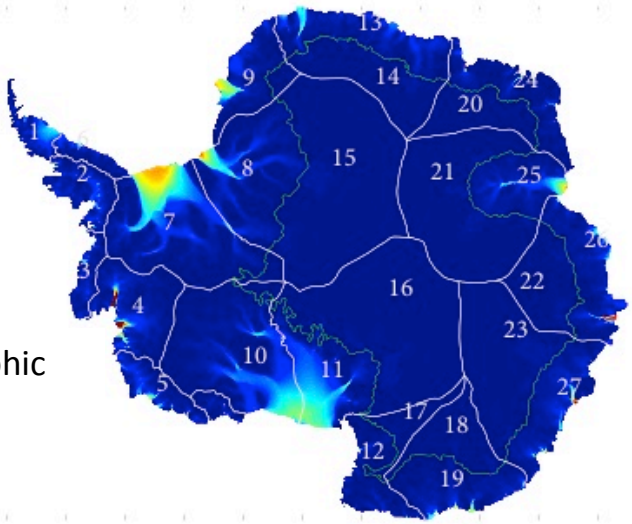

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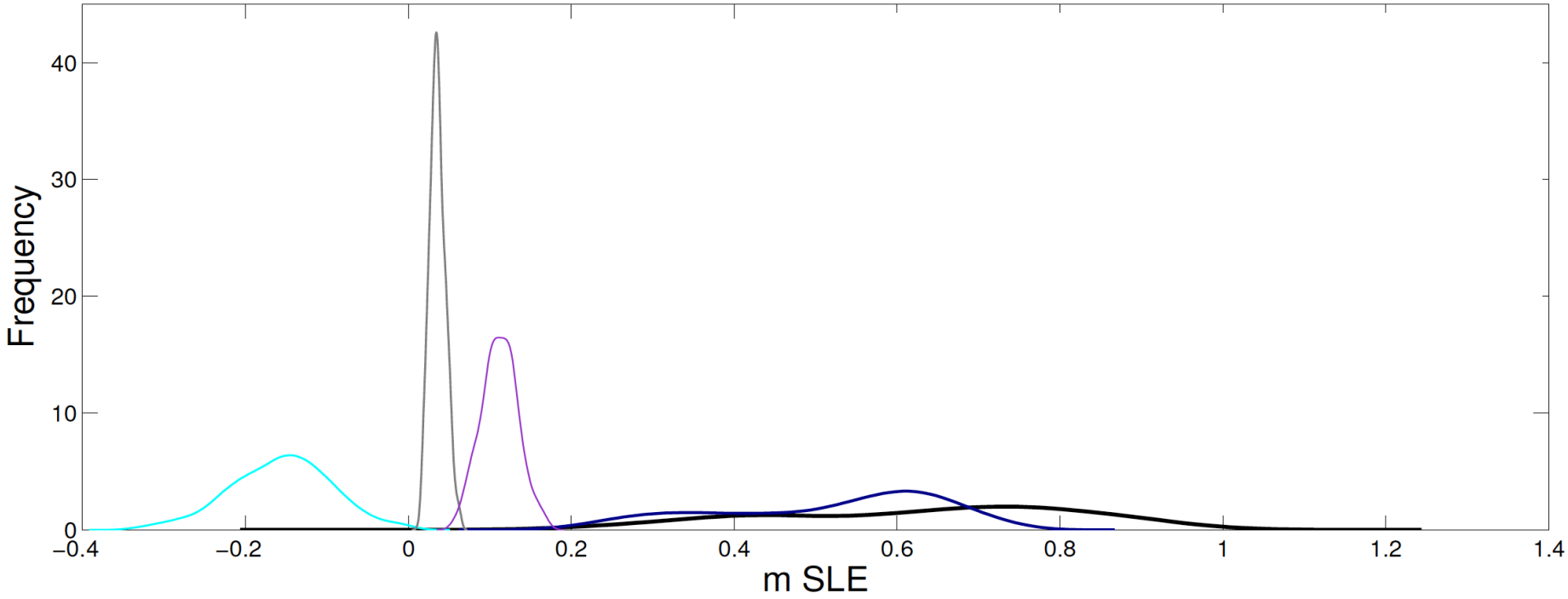
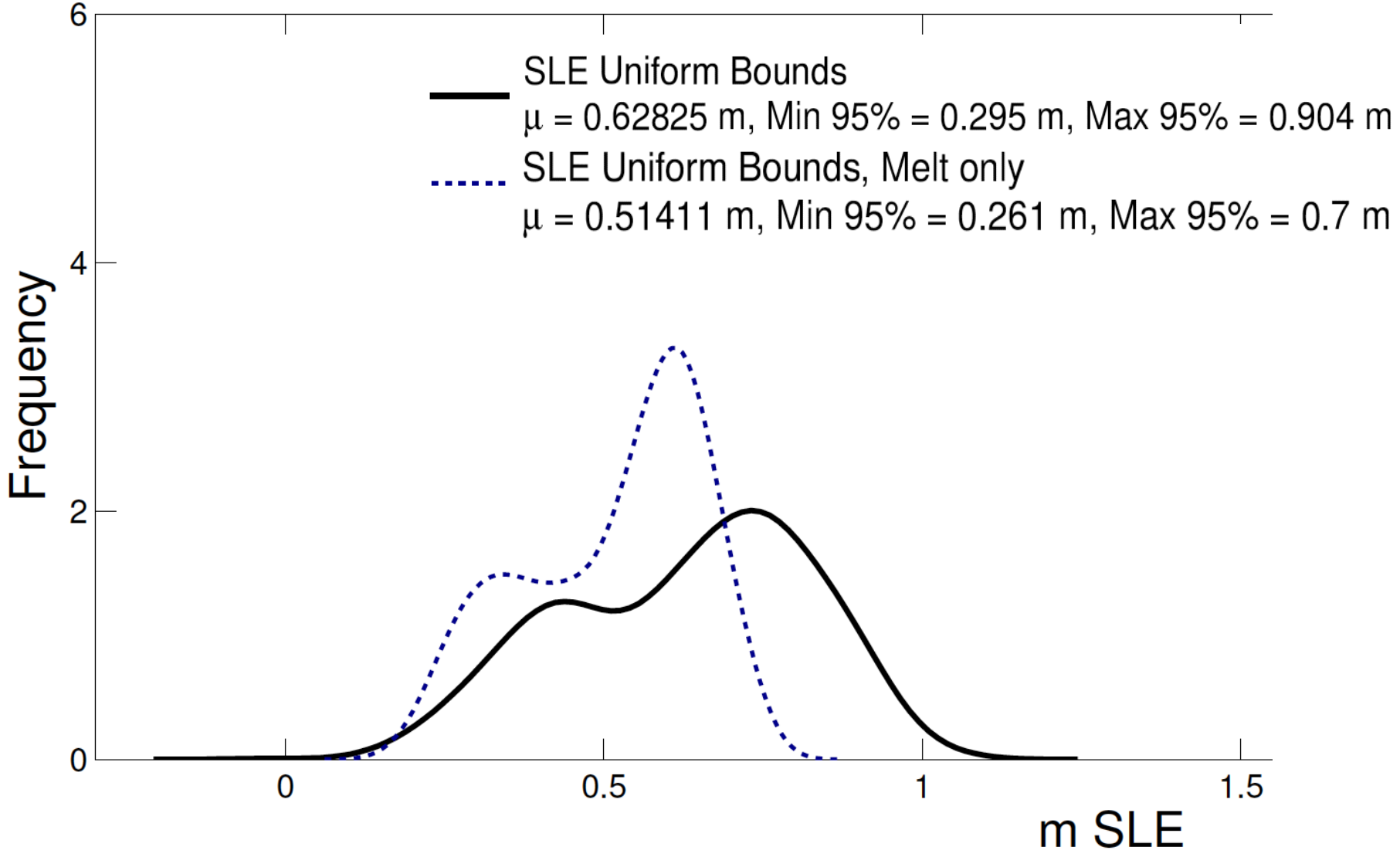
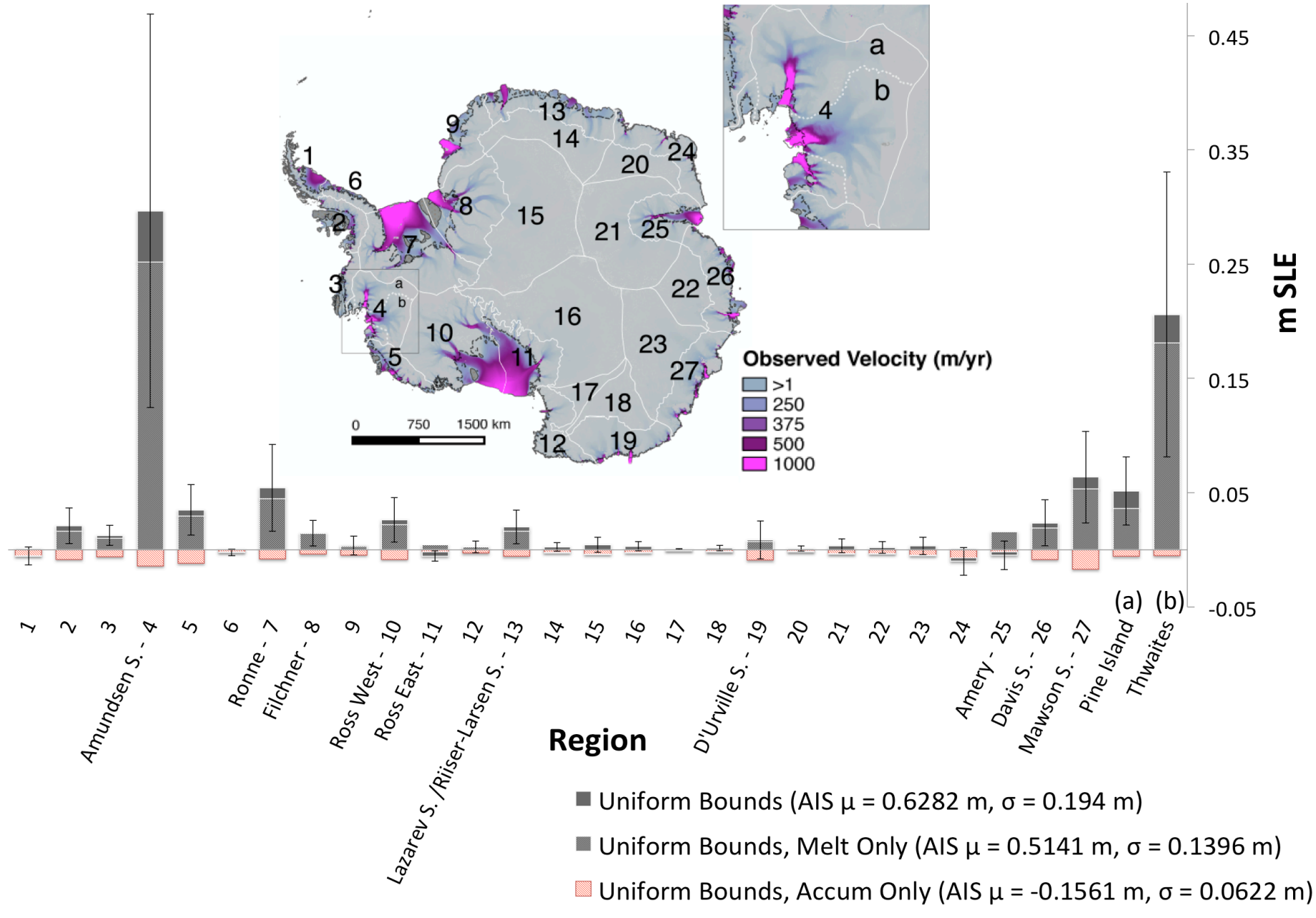


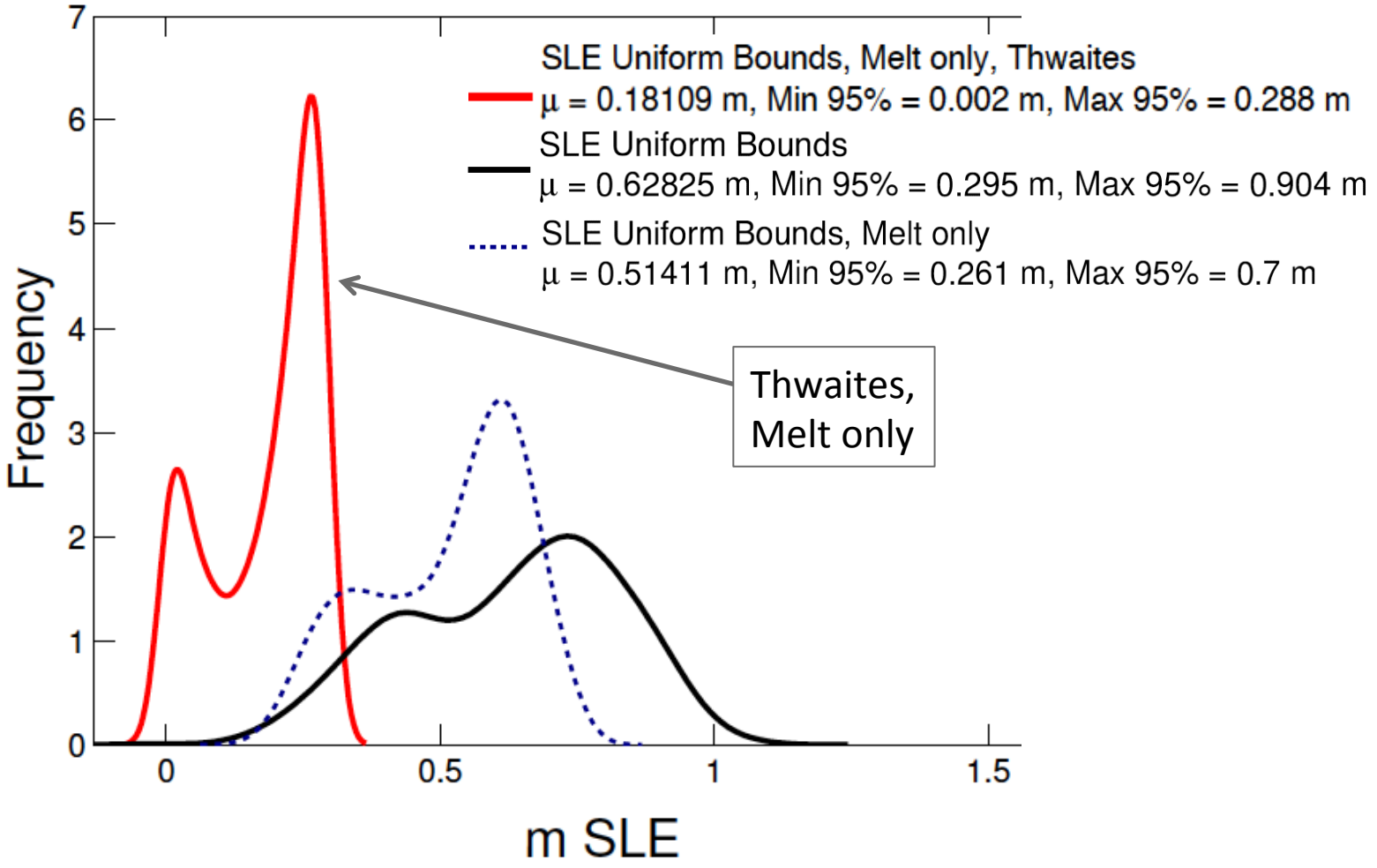
Ice Shelf Melt is responsible for a majority of the spread, and for the bimodal distribution



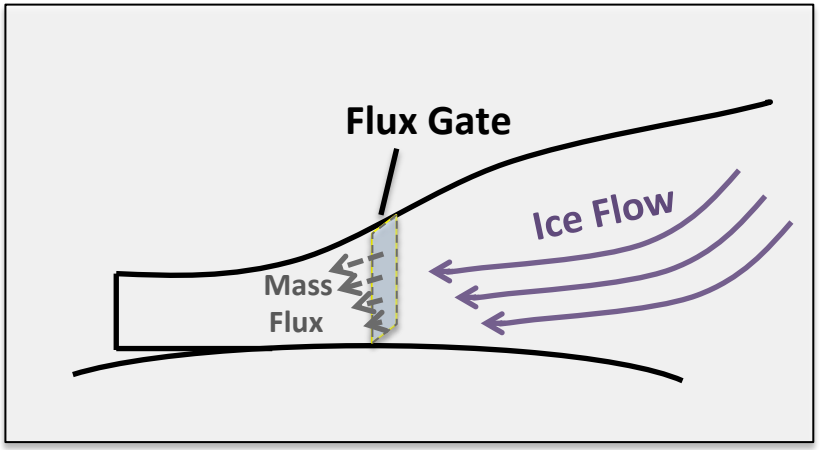
Regional analysis reveals that ice shelf melt rates for one outlet are largely responsible for uncertainty in ISSM 100-year sea level contribution

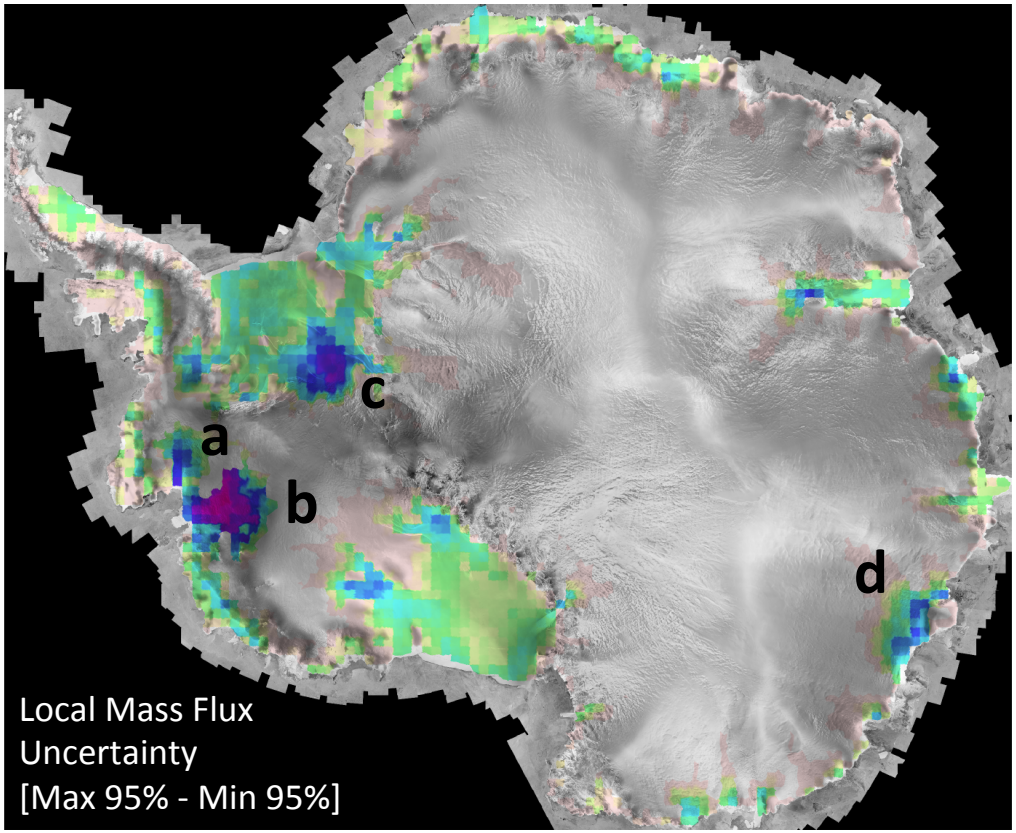


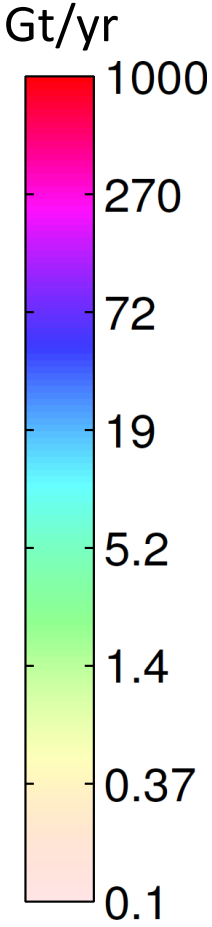
The response to ice shelf melt rates in Thwaites accounts for a majority of the uncertainty and bimodel behavior of the continental ice sheet SLE signal



Changes in ice flow dynamics contribute to uncertainty in sea level contribution in: the Amundsen Sea Sector, Ronne Ice Shelf, and Mawson Sea Sector







a - Pine Island
b - Thwaites
c - Ronne Ice Shelf (Moller/Institute)
d - Mawson Sea (Totten/Moscow U.)

Conclusions

We use uncertainty analyses to investigate how a continental ice sheet model of the Antarctic ice sheet responds to changes in forcing and boundary conditions.

- Uncertainty Quantification analysis can help us improve understanding of ice sheet model sensitivity to input error and uncertainties in projections. However, care must be taken to separate sources of uncertainties and analyze results.

- Sampling analysis allows us to quantify how results vary within a parameter space
  - Antarctica Example
    - We investigate how variables affect model SLE uncertainty, including:
      - Melt, accumulation, basal friction, and ice viscosity
    - We focus on experiments forced with extreme bounds: designed to encompass a large range of scenarios, and push the model within physically plausible limits
    - For comparison, future experiments will include setting "informed" bounds regionally, to produce a more realistic ensemble of scenarios

- Ice shelf melt rate is a key contributor to SLE uncertainty.
- Sources of uncertainty vary regionally; Regional analysis suggests that Thwaites glacier, Ronne Ice Shelf, and the Mawson Sea Sector are areas on which to focus in the future, in terms of observational and modeling efforts.

Thank you!